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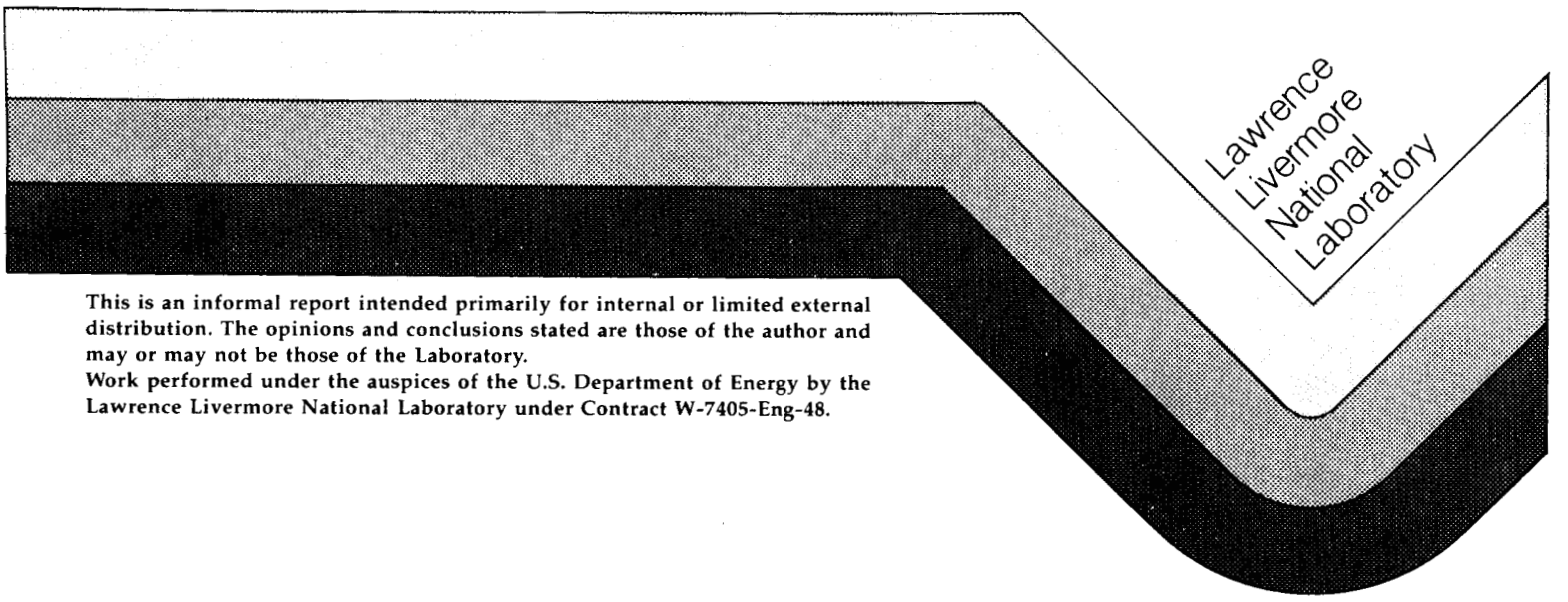
U.S. ENERGY FLOW - 1988

I. Y. Borg
C. K. Briggs

June 1989



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ABSTRACT

Trends in energy supply and use that were established in the mid-80's continued into 1988. Oil remains the largest single source of energy for the country. Overall energy consumption increased in all end-use sectors; however the greatest growth occurred in residential/commercial sectors; electrical demand increased three percent; the use of coal particularly for electrical generation increased for the eighth year; domestic oil production declined and oil imports increased; and increases in use of transportation fuels more than offset fuel economies effected by fuel standards imposed on new passenger cars since 1978. Most of the trends are a reflection on the decline in cost of all fossil fuels led by the precipitous fall of crude oil prices in the spring of 1986. During 1988 natural gas prices remained depressed and increased use would have been larger in central and northeastern sectors of the country if pipelines from western U.S. and Canada could have handled larger volumes.

INTRODUCTION

United States energy flow charts tracing primary resource supply and end-use have been prepared by members of the Energy Program and Planning groups at the Lawrence Livermore National Laboratory since 1972[1,2]. They are convenient graphical devices to show relative size of energy sources and end-uses since all fuels are compared on a common Btu basis. The amount of detail on a flow chart can vary substantially, and there is some point where complexity begins to interfere with the main objectives of the presentation. The charts shown here have been drawn so as to remain clear and be consistent with assumptions and style used previously.

ENERGY FLOW CHARTS

Figure 1 and 2 are energy flow charts for calendar years 1988 and 1987[3] respectively. The 1988 chart is based on provision data published by the Energy Information Administration of the Department of Energy. Conventions and conversion factors used in the construction of the charts are given in the Appendix. For comparison with earlier years, consumption of energy resources is given in Table 1. These data in many instances contain revisions of data initially published by the Department of Energy.

U.S. Energy Flow – 1988
Net Primary Resource Consumption 78 Quads

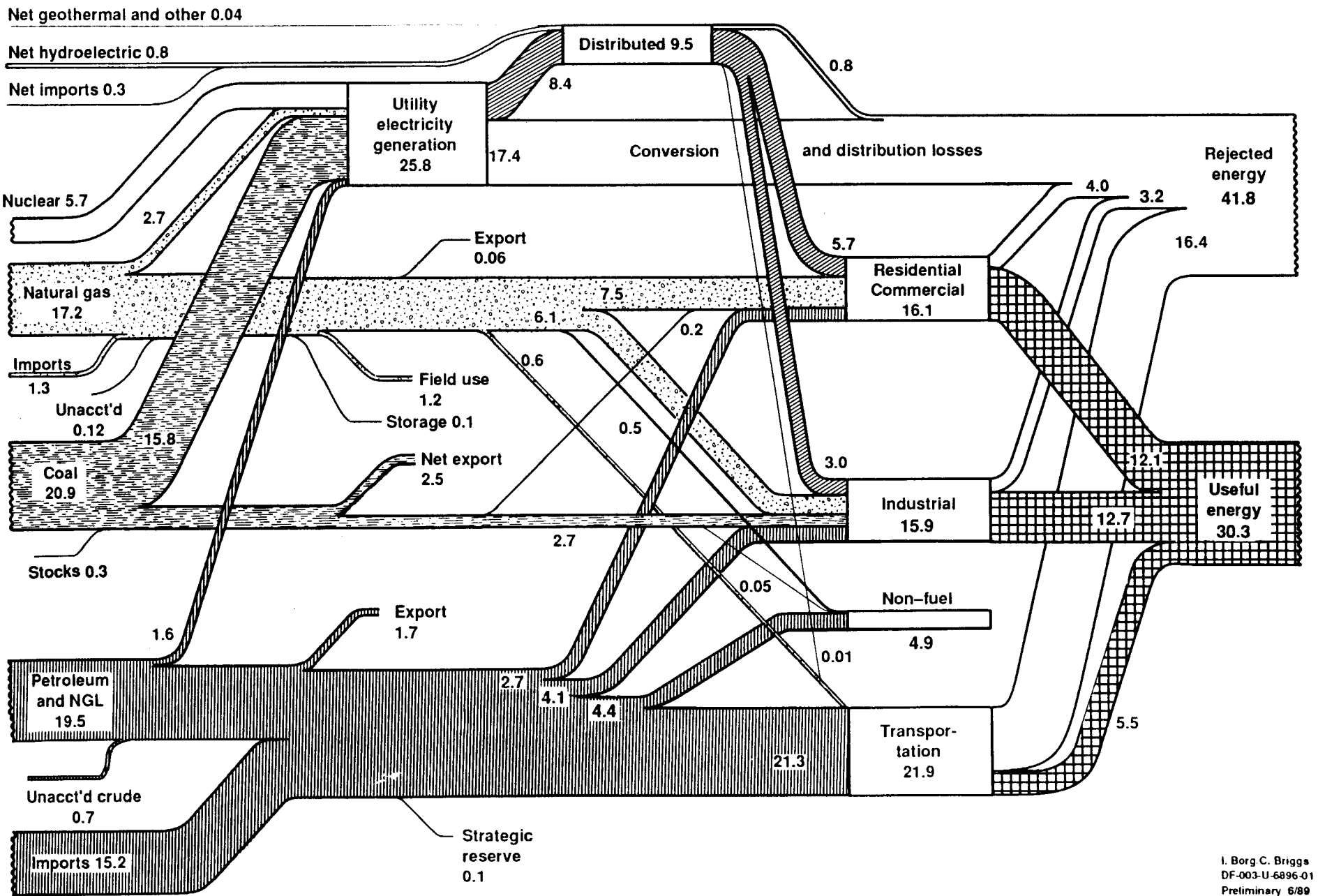

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Figure 1

U.S. Energy Flow – 1987
Net Primary Resource Consumption 76 Quads

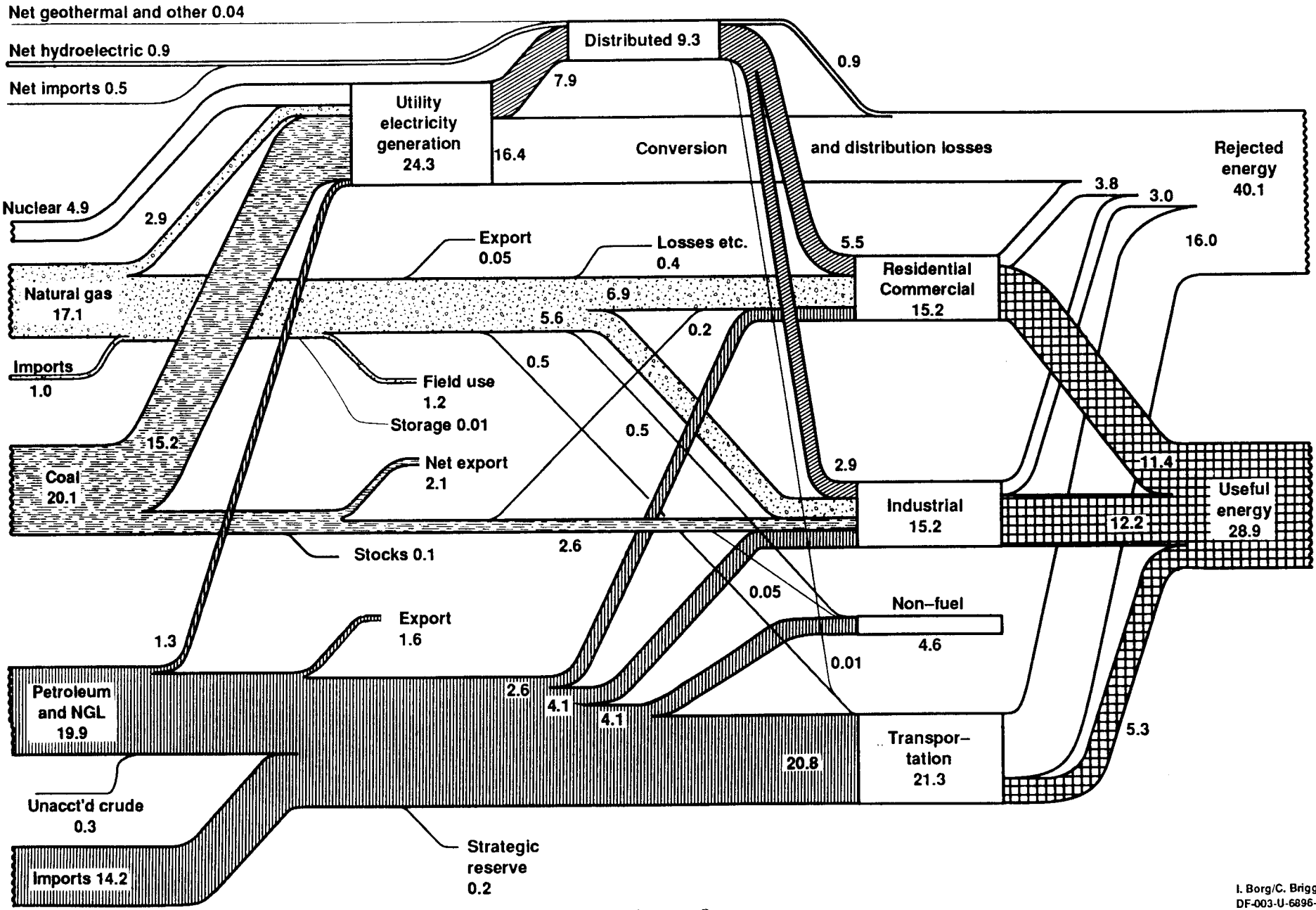

Figure 2

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Table 1. Comparison of Annual Energy Use in U.S.[4]

	Quads							
	1981	1982	1983	1984	1985	1986	1987	1988
Natural gas production	19.70	18.26	16.53	17.93	16.91	16.47	17.05	17.19
Imports	0.90	0.93	0.94	0.86	0.93	0.75	0.99	1.28
Crude oil and NGL								
Domestic crude & NGL	20.45	20.50	20.58	21.12	21.23	20.53	19.89	19.52
Foreign imports (incl. products & SPR)	12.65	10.80	10.66	11.44	10.62	13.21	14.18	15.15
Exports	1.27	1.75	1.58	1.55	1.67	1.68	1.63	1.75
SPR storage reserve*	0.71	0.37	0.49	0.42	0.24	0.11	0.17	0.11
Net use (minus exports and SPR)	31.12	29.18	29.17	30.59	29.94	31.95	32.27	32.81
Coal production (incl. exports)	18.38	18.64	17.25	19.72	19.33	19.51	20.12	20.94
Electricity								
Hydroelectric (net)								
Utility	0.89	1.06	1.13	1.10	0.96	0.99	0.85	0.76
Imports	0.35	0.31	0.37	0.41	0.42	0.37	0.48	0.30
Geothermal & other (net)	0.02	0.02	0.02	0.03	0.04	0.04	0.04	0.04
Nuclear (gross)	3.01	3.13	3.20	3.55	4.15	4.48	4.92	5.68
Fossil Fuel (gross)	18.54	17.49	17.75	18.53	18.79	18.59	19.37	20.12
Gas	3.76	3.34	3.00	3.22	3.16	2.70	2.94	2.72
Coal	12.58	12.58	13.21	14.02	14.54	14.44	15.17	15.84
Oil	2.20	1.57	1.54	1.29	1.09	1.45	1.26	1.56
Total transmitted energy	8.18	7.96	8.25	8.64	8.85	8.86	9.25	9.51
Residential and Commercial	14.54	14.63	14.40	15.01	14.90	14.83	15.20	16.14
Industrial+	22.54	20.02	19.40	21.06	20.41	20.04	21.01	22.04
Transportation	19.47	19.04	19.11	19.85	20.09	20.74	21.35	21.83
Total consumption** (DOE/EIA)	74	71	70	73	74	74	77	80

* Strategic petroleum reserve storage began in October, 1977.

\+ Includes field use of natural gas and non-fuel category and excludes electrical losses.

* * Note that this total is not the sum of entries above.

COMPARISON OF ENERGY USE WITH 1987 AND EARLIER YEARS

For the second year in a row, total energy use in the U.S. increased 4%. Increases were experienced in all end-use sectors (Table 1) with the residential/commercial sector recording the largest on a percentage basis. In the cases of both the residential/commercial and industrial sectors the increase in usage was associated with an increase in the use of natural gas. The industrial sector, despite its slightly greater energy usage, remained below historical levels (Figure 3). The break in the upward trend in industrial usage starting in the early seventies reflects the changing makeup and output of the sector and increased efficiency in many processes used. The metal and mining industries and many energy-intensive segments of U.S. industry such as cement and nitrogenous fertilizers have retrenched with a concomitant increased reliance on imports. Nonetheless, the gross national product (GNP) grew almost 4% in 1988 as compared to 3% in 1986 and 1987. Starting in 1975 services contributed more than goods to the GNP (Figure 4), which is reflected to some degree in the declining amount of energy used associated with a unit of GNP.

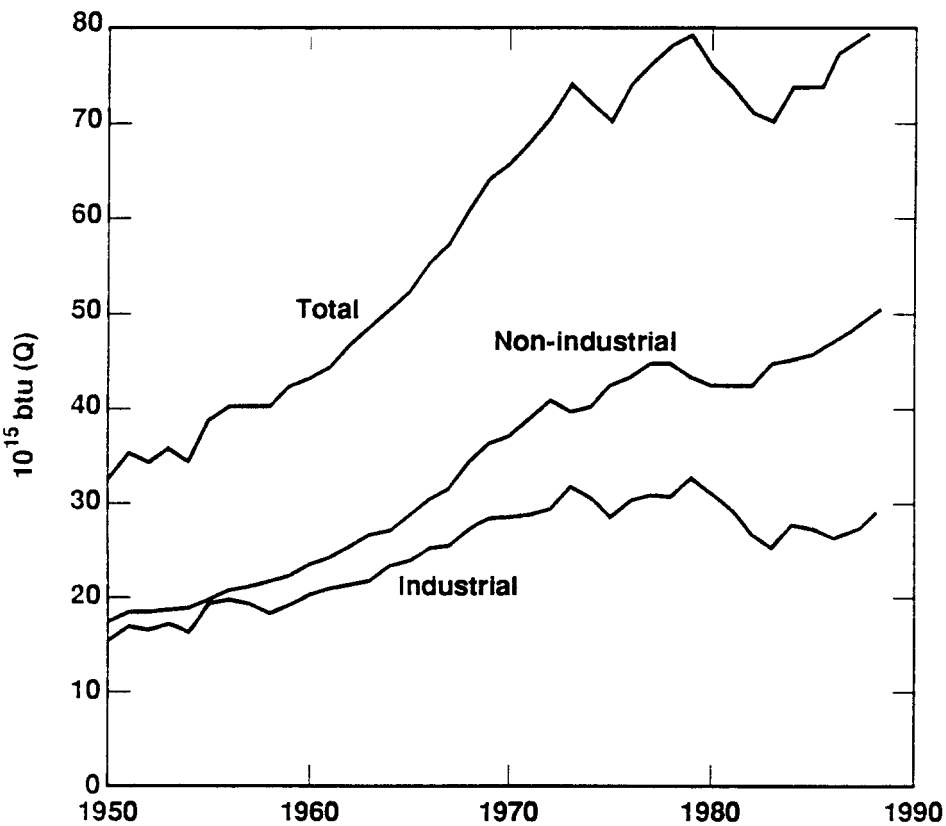


Figure 3. Energy use in U.S.[1,2]

Source: Annual Energy Review, 1988, DOE/EIA
Gross electrical use is plotted.

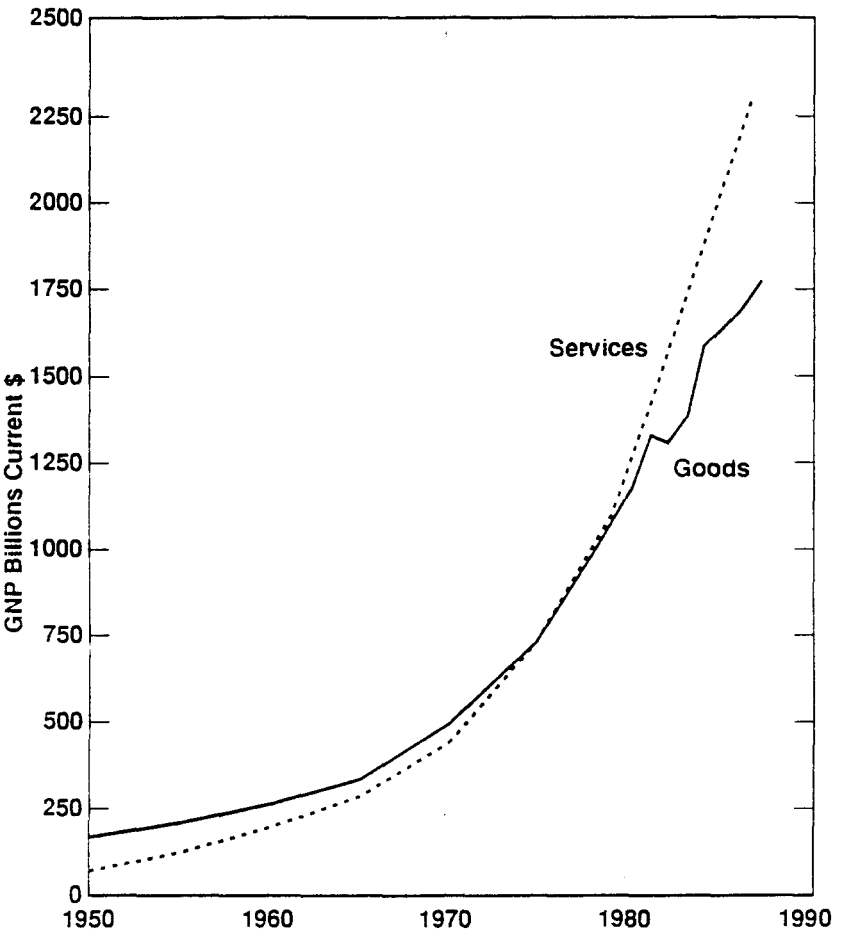


Figure 4. Components of U.S. Gross National Product
Source: Statistical Abstracts, 1989, U.S. Department of Commerce, p.410

Use of energy for transportation rose for the sixth year due to a combination of forces which more than compensated for overall improvements in fleet mileage (Figure 5). Althougn the Corporate Average Fuel Economy (CAFE) standards for new passenger cars remained at 26 miles per gallon in 1988, elimination of older, less efficient vehicles from cars on the road should result in improved mileage overall. The average mileage for all vehicles (passenger cars, trucks, buses, motorcycles, etc.) on the road in 1986, the last year for which data are available, was 14.7 miles per gallon, an improvement of 2.6 miles per gallon in the previous ten years. Over the same time span improvements for passenger cars on the road was 4.8 miles per gallon. Part of the explanation for the small improvement for the total fleet is the increasing popularity of small trucks, vans and off-road vehicles which account for a larger number of miles driven per year. Another contributing factor is that older vehicles with lower

efficiency have not been retired rapidly. This in turn reflects the relatively small portion of costs associated with owning and operating a vehicle that motor fuels comprise.

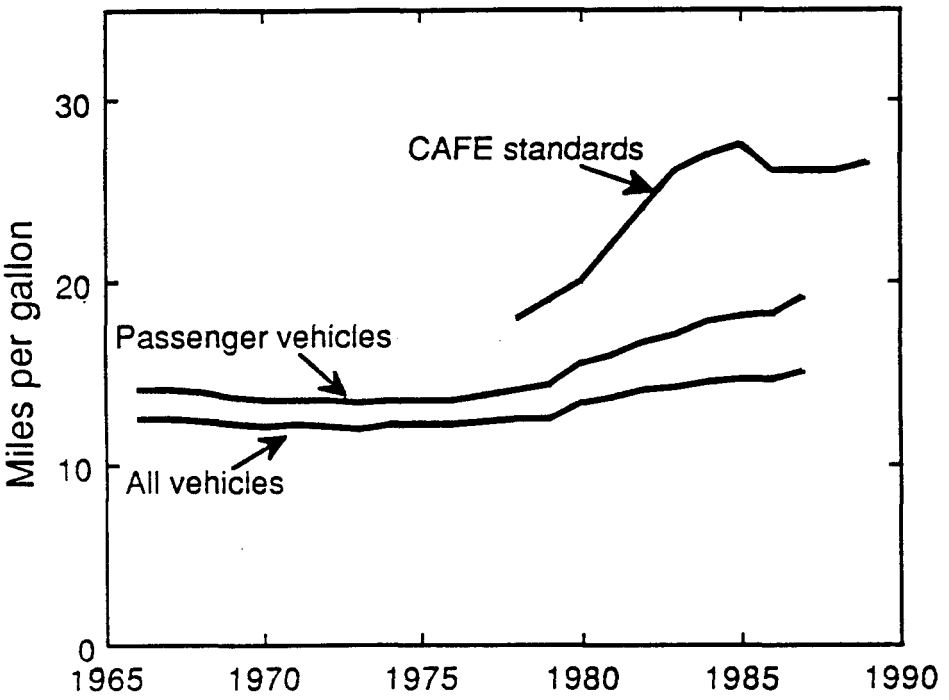


Figure 5.

Source: Annual Energy Review 1987, DOE/EIA, Table 22, p.53

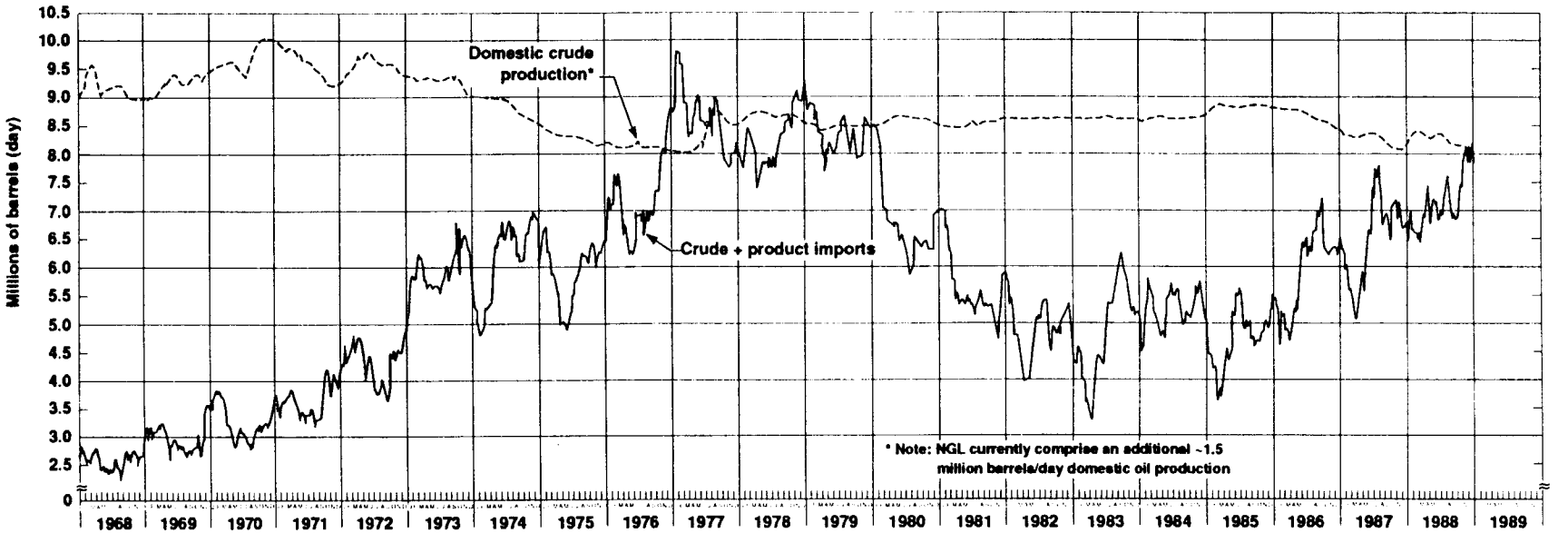
DEMAND AND SUPPLY OF FOSSIL FUELS

Use of all fossil fuels increased in 1988 with coal registering the largest increase (4.5%) due to increased demand for electrical generation. Coal exports were the highest they have been since 1982; increases were registered in both metallurgical and steam coals. Although a price gap between U. S. coals and coal from many other exporting countries is a damper on continued growth in exports, other considerations, particularly security of supply and reliability have made U.S. coals marketable. In 1988 China was unable to deliver on several export contracts because of transportation problems. Australia suffered labor problems, and Colombia in addition to having labor difficulties saw political unrest that interfered with trade.

Continued low world oil prices relative to historical highs at the start of the decade both depressed domestic production and encouraged increased oil imports (Figure 6). At year-end foreign imports comprised approximately 44% of oil supply. Non-OPEC sources of crude oil

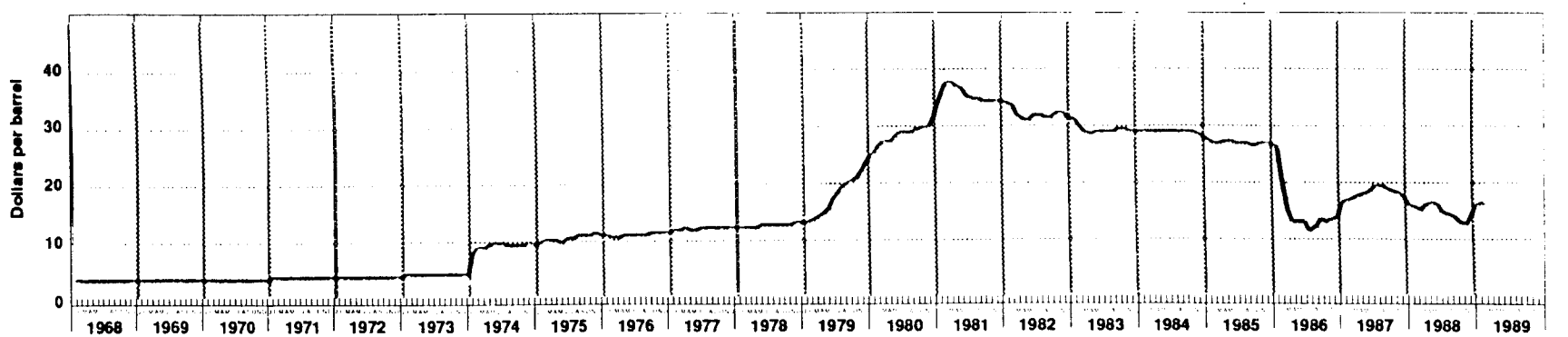
PETROLEUM IMPORTS AND DOMESTIC PRODUCTION

Moving four week average



REFINER ACQUISITION COST OF CRUDE OIL

Composite domestic and imported



I BORG

Figure 6

and products exceeded OPEC sources by less than ten percent. This is in contrast to 1985 when non-OPEC producers supplied 44% more than OPEC producers to the U.S. In 1988 the largest exporter to the U.S. was Saudi Arabia followed by Canada and Mexico whereas in 1985 Saudi Arabian oil was eighth in the list of largest exporters to the U.S.

Natural gas imports from Canada increased 28% over 1987 breaking the previous record set in 1973. Canadian imports comprise about 7% of U.S. supply. The largest growth in demand was shown in the Midwest. Because of the growing desirability of natural gas in the eyes of state and federal legislators, Canadian imports are expected to increase in the coming years; however limitation in pipeline capacity may curb rapid growth[5]. Numerous pipeline proposals were before Canada's National Energy Board at year-end. Also working against a move to substantial increase in the use of gas in the U.S. in the near future are low prices in both the U.S. and Canada, which inhibit replacement of reserves. In 1988 the average U.S. field acquisition price for natural gas was $1.83/million Btu and $2.06/million Btu for imports - less than half the price that prevailed between 1980 and 1984[6]. All exploration indicators (gas well completions, seismic crews and number of rigs operating) were at or near historical lows in 1988[7].

U.S. ELECTRICAL SUPPLY AND DEMAND

Generation by utilities (including hydropower) grew by five percent and exceeded all projections[8]. As conversion and distribution losses are approximately 67%, the growth in actual usage is proportionately smaller; thus consumption increase in principal end-use sectors was approximately 3.5%.

Non-utility generation continued to grow in the U.S. In 1988 it contributed 138.9 billion kWh of additional electricity[9]. Of this total only 56.8 GWh was sold to utilities although three quarters of total non-utility capacity was interconnected to utilities[10]. Thirty-eight percent of the non-utility generators used natural gas, non-fossil fuels [biomass, wood, waste, hydropower, etc.] (41%), coal (20%), and oil (1%) made up the remainder.

Coal remains the nation's largest fuel for power production. It constituted 57% of total fuels in 1987 and 1988. Nuclear power (19.5%) is the second and natural gas (9.4%) the third largest source (Figure 7). Use of natural gas was at 1986 levels, which is far below historical use in the seventies when it was on a par with petroleum. In 1988 hydroelectric

contribution to total power generation fell due to low rainfall in critical areas. The shortfall due to low hydroelectric contributions as well as due to increased demand was met by additional coal-fired and nuclear generation.

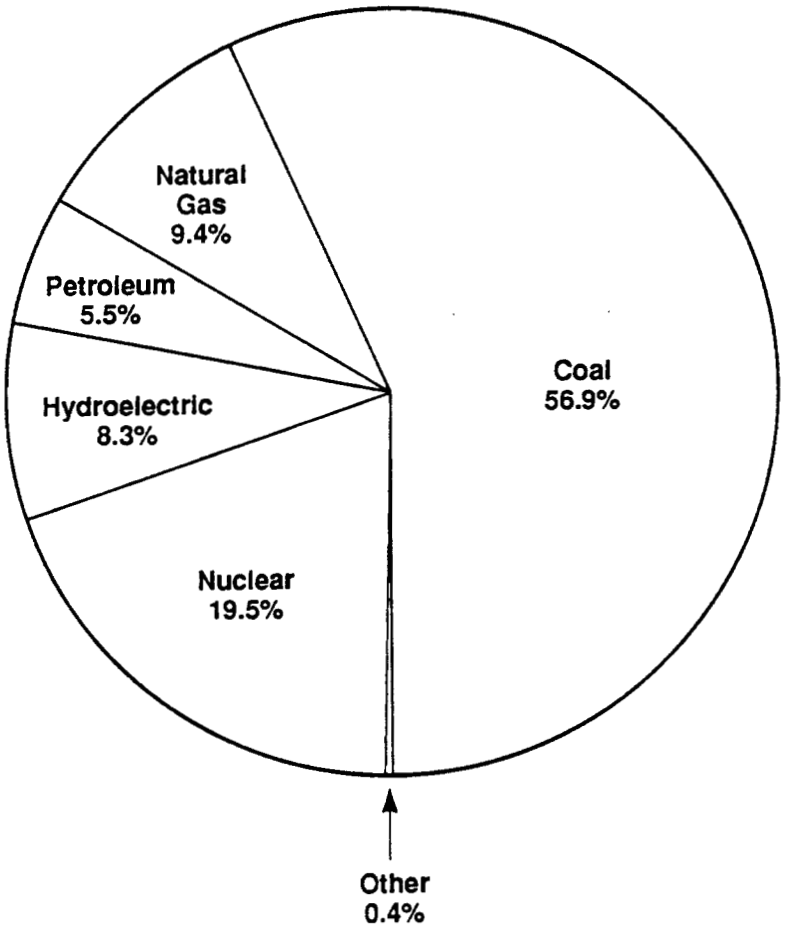


Figure 7. Fuels for U.S. electrical generation
Source: Monthly Energy Review, DOE/EIA-0035(89/1) Table 7.1

NUCLEAR POWER

Controversy concerning the wisdom of operating nuclear reactors continued unabated in 1988. The licensing of the two most contested reactors, Seabrook in New Hampshire and Shoreham in New York, crept forward with the imminent issuance of a conditional low power

license to Seabrook by year-end. Shoreham has had a similar license since 1985. However commercial operation of the two reactors remained uncertain as the opposition on state levels to both remained strong.

Some of the opposition to nuclear reactors took issues to the voters in November. For example in Massachusetts a proposal to close the state's two nuclear plants was defeated by a 68-32 percent margin despite the fact that polls taken early in the year indicated a strong support for closure[11]. Possibly voltage reductions the previous summer had not been forgotten by the voters.

A proposal that Nebraska withdraw from its interstate nuclear waste compact was similarly defeated 63-37 percent. The initiative was considered to be a first step towards retiring the state's two nuclear plants. Its defeat was a surprise in view of the fact that the owners of the plants were enjoined by the state's election commission from campaigning against the measure.

Nuclear power continued to grow in 1988; two reactors reached commercial status and one (Hanford-N unit) was shut down bringing the nation's total number of reactors to 108. In addition to two reactors (South Texas 2 and Shoreham) with low power operating licenses, there were eleven in some stage of construction; however only six have definite operational dates.

As a step toward simplifying licensing of reactors, the Nuclear Regulatory Agency formulated a series of new procedures including pre-approval of standardized reactor designs and a combined site permit and operating license. The latter proposal makes a "one step" process out of the current "two step" procedure that has proven to be time consuming and financially draining.

Nuclear contribution to total electrical generation reached 19.5 percent in 1988 (Table 2). The improvement over 1987 reflects the net increase in the number of operating reactors as well as an increase in annual capacity factors.

Table 2. Electrical generation from nuclear power[4]

	Year			
1985	1986	1987	1988	
Total utility electrical generation (bn kWh)	2469	2489	2572	2701
Nuclear contribution (bn kWh)	384	414	455	527
Percent nuclear	15.5	16.6	17.7	19.5
Installed nuclear capacity* (GWe)	79.4	85.2	93.6	95.1
Number of operable reactors	95	100	107	108
Annual nuclear capacity factor (%)	58.5	56.9	57	63.5

*Net summer capability of operable reactors

REFERENCES

1. A. L. Austin, Energy Distribution Patterns in the U.S.A. for 1970 and 1985, Lawrence Livermore National Laboratory Report UCID-16022, 1972.

2. I. Y. Borg, Energy-Flow Diagrams: An LLNL Contribution to Energy Analysis, Lawrence Livermore National Laboratory Report MISC-4500, October 1987.

3. C. K. Briggs and I. Y. Borg, U.S. Energy Flow - 1986, Lawrence Livermore National Laboratory Report UCID-19227-86, August 18, 1987.

4. Monthly Energy Review, DOE/EIA-0035 (87/12), March 1988.

5. "Limited pipeline capacity may curb U.S. imports of Canada gas short-term, says NEB," Platts Oilgram 66, No. 243, p.5, December 10, 1988.

6. Executive Gas Industry Statistics, Am. Gas Assoc., Arlington, VA, May 1989, p.2.

7. Gas Energy Review 17, No. 5, American Gas Association, Arlington, VA, May 1989, p. 4 and 15.

8. J. McCaughey, "Will 1988 settle the low v. high growth argument?", The Energy Daily 16, p.1, April 20, 1988.

9. "Bank-Energy Data Bank-Energy Data," The Energy Daily 17, p.4, May 16, 1989.

10. "Non-utility generation up by 10 percent in 1986," The Energy Daily 16, p.4, August 9, 1988.

11. J. Egan, "Nuclear wins along with Bush," The Energy Daily 16, p. 1, November 10, 1988.

12. Annual Energy Review 1988, DOE/EIA-0384(88), June 1988.

13. Quarterly Coal Report, DOE/EIA-0121(87/4Q), Table 31, May 1988.

APPENDIX

Data and Conventions Used in Construction of Energy Flow Charts

Data for the flow chart were provided by tables in the Department of Energy Monthly Energy Review, DOE/EIA-0035,[4] the 1988 Annual Energy Review[12] and the Quarterly Coal Report[13].

The residential and commercial sector consists of housing units, non-manufacturing business establishments, health and education institutions, and government office buildings. The industrial sector is made up of construction, manufacturing, agriculture, and mining establishments. The transportation sector combines private and public passenger and freight transportation and government transportation including military operations.

Utility electricity generation includes power sold by both privately and publicly owned companies. The non-fuel category of end-use consists of fuels that are not burned to produce heat, e.g., asphalt, road oil, petrochemical feedstocks such as ethane, liquid petroleum gases, lubricants, petroleum coke, waxes, carbon black and crude tar. Coking coal traditionally is not included.

The division between "useful" and "rejected" energy is arbitrary and depends on assumed efficiencies of conversion processes. In the residential and commercial end-use sectors, a 75 percent efficiency was assumed which is a weighted average between space heating at approximately 60 percent and electrical lighting and other electrical uses at about 90 percent. Eighty percent efficiency was assumed in the industrial end-use sector and 25 percent in transportation. The latter percent corresponds to the approximate efficiency of the internal combustion engine.

There are some minor differences between total energy consumption shown here in the energy flow charts and the DOE/EIA totals given in Table 1. The total energy requirement reported here differs from the total reported by the Department of Energy by one plus quads. The Department of Energy reports the gross amount of energy associated with hydroelectric generation whereas our preference is to report net electrical generation associated with hydroelectric power, i.e., calculated from the number of kWh produced. The difference between the two is the assumed efficiency of the conversion process, plant use combined with

distribution losses. Regardless of fuel or resource, the Department of Energy assumes such losses at 66% which may be a good approximation for fossil fuels but is too high for hydroelectric power generation where the conversion efficiency is closer to 80%. By using the net figure rather than the gross for hydroelectric power we omit not only true losses associated with hydroelectric generation but probably some losses that are more properly associated with use of fossil and nuclear fuel.

The industrial consumption total in Table 1 agrees with DOE's net industrial total. Both totals include natural gas lease and plant fuel and non-fuel ("non-energy") use, which are shown separately in the flow charts (Figure 1 & 2). Gross industrial consumption plotted in Figure 3 includes electrical conversion and distribution losses, which are not specifically given in Figures 1 & 2. These losses are included in total electrical generation losses (17.4 Q) associated with utility generation in Figures 1 & 2 because such losses are largely incurred by the utilities supplying the electrical power to the sector.

Conversion Factors

The energy content of fuels varies. Some approximate, rounded conversion factors, useful for estimation, are given below.

Fuel	Energy Content (Btu)
Short ton of coal	22,400,000
Barrel (42 gallons) of crude oil	5,800,000
Cubic foot of natural gas	1,000
Kilowatt hour of electricity	3,400

More detailed conversion factors are given in the Department of Energy's Monthly Energy Review.

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